

# Community-based beekeeping practices of *Apis cerana* in the Ir. H. Djuanda Great Forest Park, West Java, Indonesia

INDRI WULANDARI<sup>1,2,3,\*</sup>, TEGUH HUSODO<sup>1,2,3</sup>, DEA NAVITA HASANAH<sup>1</sup>, FADIAH KHAIRINA<sup>3</sup>,  
SYA SYA SHANIDA<sup>3</sup>

<sup>1</sup>Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran. Jl. Raya Bandung-Sumedang Km. 21, Jatinangor, Sumedang 45363, West Java, Indonesia. Tel. +62-22-7796412 ext. 104, Fax. +62-22-7794545. \*email: indri.wulandari@unpad.ac.id

<sup>2</sup>Department of Environmental Science, School of Graduates, Universitas Padjadjaran. Jl. Sekeloa, Coblong, Bandung 40134, West Java, Indonesia

<sup>3</sup>Pusat Unggulan IPTEK Perguruan Tinggi, Center of Environment and Sustainable Science, Directorate of Research, Community Services and Innovation, Universitas Padjadjaran. Jl. Sekeloa, Coblong, Bandung 40134, West Java, Indonesia

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**Abstract.** Wulandari I, Husodo T, Hasanah DN, Khairina F, Shanida SS. 2026. Community-based beekeeping practices of *Apis cerana* in the Ir. H. Djuanda Great Forest Park, West Java, Indonesia. *Asian J Ethnobiol* 9 (1): y090116. <https://doi.org/10.13057/asianjethnobiol/y090116>. Asian honey bee (*Apis cerana*) beekeeping provides essential livelihood support for local communities in Indonesia. However, their population has declined due to land-use changes, pesticide exposure, and inadequate beekeeping practices, while knowledge of their biology and management remains limited. This study aims to document local knowledge and beekeeping practices in the Ir. H. Djuanda Great Forest Park (DGFP), West Java, Indonesia. The research was conducted in July 2025 using a mixed-methods approach combining qualitative and quantitative interviews. Sampling consisted of a census of 35 beekeepers and five purposively selected key informants, selected for their experience and involvement in community-based beekeeping. Results highlight the continued dominance of traditional beehive systems (66%), reflecting long-established techniques and familiarity with materials. *Albizia* sp. is the most widely used beehive wood (69%), preferred for its lightweight, availability, and affordability. Beekeeping sites are strongly forest-oriented, with colonies commonly placed in shaded, resource-rich areas in Batu Garok (BG: 39%), Deer Enclosure (DE: 64%), and Maribaya (MB: 50%). Additional practices include constructing beehives with standardized dimensions, selecting sites based on floral availability, conducting routine maintenance, and mitigating pests and predators. The main beehive types used are traditional *glodok* and box hives, chosen for durability and ease of management. These findings underscore the important role of local knowledge in supporting the persistence of *A. cerana* and forest-compatible livelihoods. Strengthening technical capacity, especially in value-added products such as propolis and royal jelly, may enhance economic resilience and sustain community-based beekeeping in DGFP.

**Keywords:** *Apis cerana*, colony management, pollinator, rural livelihood

## INTRODUCTION

For centuries, beekeeping has been practiced throughout Indonesia, playing an important, though underrecognized, role in supporting the livelihoods and cultural heritage of many indigenous and traditional communities (Gratzer et al. 2019; Harianja et al. 2023). Multiple honey bee species occur in the country. Still, beekeepers predominantly manage Asian honey bees (*Apis cerana*) because they are docile, resilient to pests and pathogens, adaptable to tropical climates and extreme weather, and easy to breed (Gratzer et al. 2019; Nuraini and Purwanto 2021; Anita et al. 2022). Besides, this species exhibits effective grooming and hygiene behaviours and cooperative colony defence capabilities (Park et al. 2015), making it especially suited to smallholder and forest-edge beekeeping systems.

Despite its ecological adaptability, *A. cerana* populations have declined across several Asian countries (Theisen-Jones and Bienefeld 2016; Kortsch et al. 2024), due to land-use change, pesticide exposure, habitat degradation, and poor management practices (Hanifa et al.

2021). Knowledge of bees' biology and ecological behavior is essential in apiculture, as it helps understand the associated problems and their management (Aryal 2019; Amakpe and Sinsin 2025). Still, such understanding must be complemented by insights into the knowledge systems of the communities that actively maintain the colonies.

An ethnobiological approach that records a community's knowledge of species management can serve as the basis for biodiversity conservation initiatives (Athayde et al. 2016). Communities living around Ir. H. Djuanda Great Forest Park (DGFP), West Java, Indonesia, have utilized honey bees through beekeeping practices for many years (Husodo et al. 2024). When practicing beekeeping, communities are guided by local knowledge of bee management in their environments (Kahono et al. 2021). Local knowledge originates from inherited traditions or personal experiences, is developed and preserved over generations, and is generally spread orally in the native language (Mahbub et al. 2019). Local knowledge of cultural practices can be lost if it is not passed on to the next generation, so it is essential to document it (Helida et al. 2016; Rodrigues et al. 2022).

Fajari et al. (2023) documented the knowledge of collecting honey from stingless bees (*Tetragonula* sp.) in Sumedang District, West Java, but comparable documentation of *A. cerana* remains scarce.

DGFP is one of the prominent centers of *A. cerana* beekeeping. Several studies have examined ecological aspects of *A. cerana* in this landscape. These include investigations of pollen resources (Nuriyah et al. 2021a), ecosystem services (Nuriyah et al. 2021b), the flowering calendar and pollen resources (Husodo et al. 2024; Amalia et al. 2025; Wulandari et al. 2025), and hive monitoring using sensor-based technologies (Kviesis et al. 2020). Collectively, these studies highlight the ecological role of *A. cerana* and demonstrate that floral resources in DGFP fluctuate seasonally, creating periods of scarcity that threaten colony persistence.

However, what remains undocumented is how local beekeepers interpret and respond to these ecological constraints and how their knowledge is translated into practical management decisions. None of the previous studies in DGFP has documented the knowledge that guides hive construction, site selection, colony maintenance, pest management, and harvesting strategies. This gap is critical because the sustainable management of *A. cerana* depends not only on ecological factors but also on the cultural and experiential knowledge embedded in local communities.

Given the ecological importance of *A. cerana*, the seasonal variability of floral resources in DGFP, and the absence of studies on community-based management practices, there is an urgent need to document how beekeepers apply local knowledge to maintain colonies under dynamic forest conditions. Understanding these practices is essential for strengthening sustainable

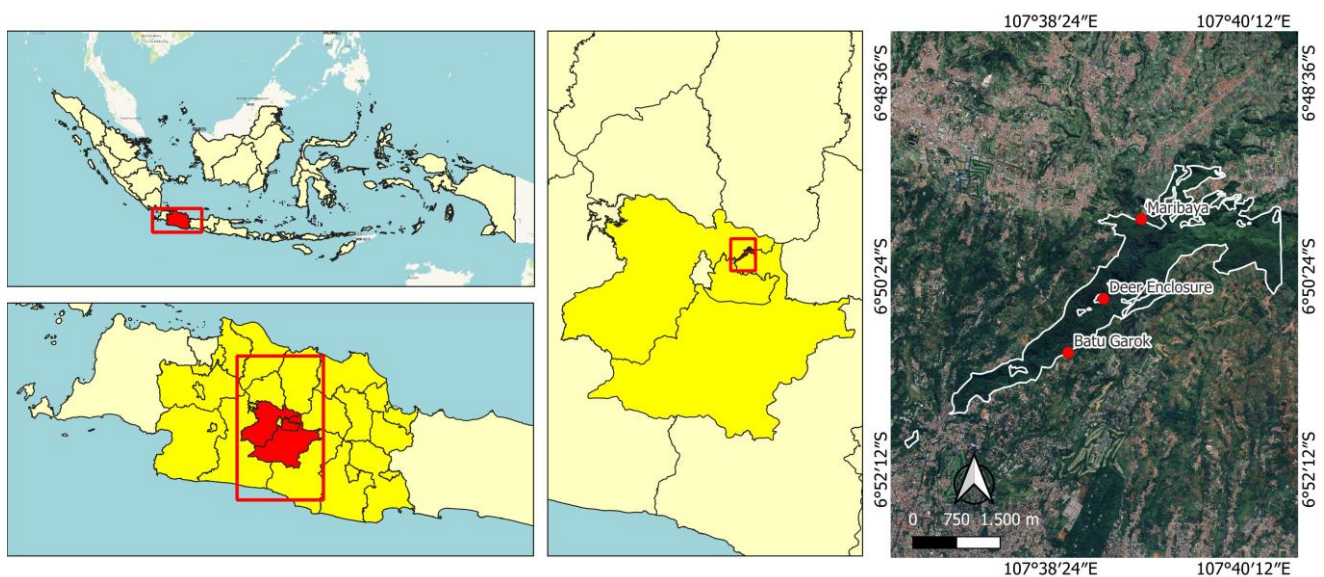
beekeeping, promoting forest conservation, and supporting rural livelihoods.

Therefore, this study aims to document the local ecological knowledge and management practices of *A. cerana* beekeepers in DGFP. Specifically, the study focuses on how beekeepers evaluate differences in hive-site characteristics across sites, which wood species and hive designs they prefer, how they maintain colonies through routine and seasonal activities, and what strategies they use to reduce absconding. By placing these practices within DGFP's dynamic ecological context, this study provides an integrated picture of *A. cerana* colony management in the region. It offers insights for apiculture compatible with conservation and livelihood sustainability at the forest edge.

## MATERIALS AND METHODS

### Study area

The study was conducted in July 2025 (two weeks in the field) at DGFP, Bandung, West Java, Indonesia (Figure 1). DGFP is located in the Bandung District (Ciburial Village), West Bandung District (Mekarwangi Village, Cibodas Village, Langensari Village, and Wangunharja Village), and Bandung City (Dago Village) (Ervinia et al. 2020). DGFP covers 528,393 hectares, including plantation forests (475,158 ha), secondary forests (19,652 ha), shrubs (29,558 ha), ponds (1,187 ha), and open areas (2,838 ha) (All land-cover data from Nuriyah et al. 2021a; Wulandari et al. 2025). *Apis cerana* beekeeping centers are located in Batu Garok (BG), Deer Enclosure (DE), and Maribaya (MB) (Nuriyah et al. 2021a, b; Husodo et al. 2024; Wulandari et al. 2025).



**Figure 1.** Map of Ir. H. Djuanda Great Forest Park (DGFP), West Java, Indonesia, showing the three beekeeping sites: Batu Garok (BG; 6°51'6.51\"S 107°38'33.97\"E), Deer Enclosure/*Kandang Rusa* (DE; 6°50'36.43\"S 107°38'53.75\"E), and Maribaya (MB; 6°49'51.96\"S 107°39'14.94\"E). Source: Nuriyah et al. (2021a)

BG is located in Ciburial Village, Cimenyan Sub-district, Bandung District. Ciburial Village is located between 750 and 1,200 meters above sea level (m.a.s.l.). *A. cerana* beekeeping in BG is carried out by community members of the Asy-Syifa Babussalam Forest Farmers Group (KTH).

DE is located within the DGFP in Mekarwangi Village, Lembang Sub-district, West Bandung District. This site is located at approximately 900 m.a.s.l. It is located near a dam that supplies water to the Cikapundung River (the water level ranges from 70 to 140 meters).

MB is located in the northern part of DGFP. Administratively, it is in Langensari Village, Lembang Sub-district, West Bandung District. Langensari Village is located at an elevation of approximately 1,200 m.a.s.l. This beekeeping is located in a forest area owned by the Forestry Service. The people of Langensari Village, most of whom are members of KTH Sari Alam and KTH Asli Alam, engage in *A. cerana* beekeeping in MB.

### Procedures

The study employed a mixed methods approach, combining qualitative and quantitative methods. Qualitative methods are approaches used to explore local ecological knowledge (Creswell and Creswell 2018), while quantitative methods are used to capture patterns in beehive construction, beekeeping site selection, beehive maintenance practices, harvesting, and marketing that can be analyzed statistically. Combining quantitative and qualitative data will provide a more complete understanding of a research problem (Creswell and Creswell 2018).

#### *Semi-structured interview*

Semi-structured interviews were conducted to document local ecological knowledge related to the general characteristics of *A. cerana*, including its behavior, morphology, life cycle, beehive construction, seasonal challenges, natural enemies, colony management practices, beehive maintenance practices, harvesting, and marketing. Interview questions explored beekeepers' experiences in selecting hive locations, material used for hive construction and dimensions, strategies for preventing colony absconding, natural enemies affecting colonies, honey harvesting methods, and product marketing practices. Five key informants were selected purposively (Iskandar et al. 2016), based on criteria: (i) >20 years of beekeeping experience and/or (ii) leadership roles in beekeeping groups. The semi-structured interview was conducted using in-depth interview guidelines, prepared in advance and developed during the interviews (Husodo et al. 2019). All key informants were approached in person, and interviews were conducted face-to-face at the beekeeping sites.

#### *Structured interview*

Structured interviews were conducted to capture patterns in beehive construction, beekeeping site selection, beehive maintenance practices, harvesting, and marketing. The questionnaire included questions on preferred hive materials, preferred hive placement, timing of hive transfer,

frequency of colony monitoring, and honey marketing channels. Interviews were conducted using a questionnaire administered to respondents, including questions about their identities, followed by questions related to the research topic. The respondents were selected through a census approach to all beekeepers (n=35) across the three beekeeping sites. For this study, a beekeeper was operationally defined as an individual who: (i) managed at least one active *A. cerana* colony within the last 12 months, (ii) owned or supervised colonies located in one of the three sites, and (iii) directly participated in routine maintenance or harvesting activities. Individuals who had stopped beekeeping for more than one year or who only assisted occasionally were excluded.

### Data analysis

The qualitative data were analysed through a structured process of cross-checking, summarizing, and synthesizing, adapted from Newing et al. (2011), Partasasmita et al. (2019) and Iskandar and Iskandar (2021). Cross-checking was conducted through data triangulation, comparing information from different key informants to ensure internal consistency. Interview transcripts were summarized to extract statements relevant to *A. cerana* beekeeping, which served as the basis for thematic coding and synthesis into broader ecological knowledge themes.

The quantitative data were analysed using percentages to determine patterns in beehive construction, site selection, colony transfer timing, maintenance, harvesting frequency, and marketing channel. Fisher's exact test was used to assess the relationship between categorical variables across sites (Shan and Gerstenberger 2017). This test is commonly used to compare the presence or absence of taxa across locations or land cover types, particularly in studies with small sample sizes or rare taxa (Currie et al. 2022; Ban et al. 2023; García et al. 2025). It was chosen because sparse contingency tables violated chi-squared assumptions (Kim 2017; Shan and Gerstenberger 2017; Kroonenberg and Verbeek 2018). This condition was present in all the tables in this study. Therefore, Fisher's Exact Test provided a more accurate and unbiased probability estimate when testing the null hypothesis of independence between variables (Kim 2017). Data analysis was performed using IBM SPSS Statistics.

For a 2×2 table, the exact probability was calculated using the classical hypergeometric formula, where a, b, c, and d represent the observed frequencies, and N represents the total sample size.

$$p = \frac{(a + b)! (c + d)! (a + c)! (b + d)!}{N! a! b! c! d!}$$

For larger tables (R×C), the calculation was extended using the Freeman–Halton approach, which determines the exact probability of the observed table configuration by conditioning on the total number of rows and columns. Since the data used in this study were R×C tables (e.g., species × three locations), the above formula was extended for R×C tables. This gives the exact probability (P<sub>obs</sub>) of observing a particular table with fixed total rows (R<sub>i</sub>) and total columns (C<sub>j</sub>) (fixed margins) (Mehta and Patel 2016).

$$P_{obs} = \frac{\prod_{i=1}^R R_i! \times \prod_{j=1}^C C_j!}{N! \prod_{i=1}^R \sum_{j=1}^C n_{ij}!}$$

This approach evaluated all possible alternative tables with fixed margins. It calculated the probability of the observed table, in accordance with the basic principles of exact tests, as described by Shan and Gerstenberger (2017). Since the Fisher's test results were significant ( $\alpha=0.05$ ), the analysis continued with a post hoc paired-comparison test to identify differing site pairs. The  $R \times C$  table was divided into several  $2 \times 2$  or  $R \times 2$  sub-tables, with each analysis comparing only two places at a time (e.g., BG vs DE, BG vs MB, and DE vs MB). Fisher's Exact Test was used at all post hoc stages because splitting the table reduced the sample size and made the data distribution sparser.

Post hoc p-values were evaluated at  $\alpha=0.05$  without multiple-comparison correction to avoid overlooking essential differences in small samples (Ranganathan and Aggarwal 2018). However, this approach increases the risk of Type I error (false positives), and therefore, the pairwise comparisons should be interpreted with caution. For each comparison, the exact probability was computed using the same formula, where  $N_{sub}$  is the total sample size of the two compared sites.

$$p = \frac{(a+b)! (c+d)! (a+c)! (b+d)!}{N_{sub}! a! b! c! d!}$$

### Ethics statement

This study involved human participants and followed international ethical guidelines for ethnobiological and community-based research. The Universitas Padjadjaran granted ethical approval under protocol number 592/UN6.D/KP.010/2025. Research permission to conduct interviews and field observations was issued by the management authority of Ir. H. Djuanda Great Forest Park under permit number 65/HM.03.05/U.PTHR. Before data collection, all participants were informed of the study's objectives, the voluntary nature of their participation, and their right to withdraw at any time without consequences. Informed consent was obtained verbally and documented before each interview, in accordance with culturally appropriate procedures commonly used in community-based research. No personal identifiers were collected. All responses were anonymized during transcription and analysis to protect participant privacy. Data were stored securely in password-protected files accessible only to the research team.

## RESULTS AND DISCUSSION

### Beekeepers profiles

A total of 35 respondents and five informants were interviewed for this study (see Tables 1 and 2). Beekeepers around the DGFP were predominantly male (82.9%), middle-aged (40-60 years old) (71.4%), had an elementary school education (45.7%), and had less than ten years of experience (68.6%).

### General characteristics of *A. cerana*

The local community commonly refers to *A. cerana* bees as *nyiruan* (Sundanese). They have black bodies in the front (chest) and yellow bodies in the back (abdomen), with thick black stripes. Younger queen bees are light brown, while older queens are black. Unlike worker bees, the queen has very thin lines or no lines at all on her abdomen. The queen has a stinger that she uses to fight other queen bees and defend the colony. Male bees are generally dark black or brown.

The beekeepers (5 of 5 informants) tend to choose *A. cerana* because it is the most adaptable to local environmental conditions. Other species, such as *A. mellifera*, are considered less adaptable, while *Trigona* yields less honey, and *A. dorsata* is aggressive and nests in inaccessible trees. *Apis cerana* is docile, making it easy to cultivate. It usually forages within 400-700 m of the hive, with a maximum distance of 3 km. Furthermore, informants mentioned that this species diligently maintains cleanliness by discarding larval molts and cell coverings outside the hive.

The life cycle of honey bees starts when the queen lays eggs in cells within the hive, then progresses through larva, pupa, and adult stages. Larvae were described as small, white, and oval-shaped with a curved body. Bee eggs are small, white, and oval-shaped, resembling grains of rice, and hatch in about three days.

According to beekeepers, worker bees initially feed the larvae royal jelly in open hive cells, then provide a mixture of pollen and nectar. Worker bees continuously feed royal jelly to selected queen candidates. After about five days, worker bees seal larval cells with wax. The pupal stage resembles adult bees but with undeveloped wings. The pupae emerge as fully developed adults. The developmental period varies by caste: queens take about 16 days, males 24 days, and workers 21 days.

### Beehive types and construction

Two beehive types were applied in the DGFP: traditional and modern. Traditional beehives are simple structures, such as wooden logs (*glodok*) or wooden boxes (Figure 2). Beekeepers reported that in traditional hives, *A. cerana* can build combs of varying thickness, resulting in higher honey yields. These hives can be made from locally available materials. However, a disadvantage is that harvested honey often contains larvae because there is no clear separation between the honey storage area and breeding area. Modern beehives are wooden boxes equipped with frames (Figure 2). These frames regulate the comb's shape and prevent it from attaching to the hive walls. The advantage is that honey can be harvested more hygienically, without damaging brood combs due to the clear separation between the storage and breeding areas. However, frames may restrict comb expansion.

BG predominantly used traditional types, whereas a larger proportion of beekeepers at DE and MB adopted combined systems, and MB consisted entirely of combined beehives (Figure 3). These differences were statistically significant (Fisher's Exact Test,  $p=0.001$ ), and post-hoc comparisons confirmed that BG differed from both DE

( $p=0.010$ ) and MB ( $p=0.011$ ), while DE and MB did not differ ( $p=0.650$ ).

The construction of beehives represents the initial stage of beekeeping. Beekeepers often use leftover wood, either collected from forests or purchased. They commonly used wood species, such as albizia (*Albizia* sp.), toona tree (*Toona sinensis*), Indian coral tree (*Erythrina variegata*), and sugar palm (*Arenga pinnata*). Beekeepers reported that ideal beehive wood should be strong and resistant to excessive heat and humidity. *Albizia* sp. is the most preferred wood (Figure 4) due to its lightweight, availability, and affordability.

*Toona sinensis* is known for its strength, durability, and aroma that attracts honeybees, but it is relatively expensive. *E. variegata* regulates temperature by absorbing heat, keeping the beehive cool during the dry season. *Arenga pinnata* is dense and often used for *glodok*-type beehives due to its insulation capacity and durability. Statistical test confirmed no significant differences in wood preference among sites ( $p=0.388$ ), and all pairwise comparisons were also non-significant ( $p\geq 0.184$ ).

The species and size of the wood used are both important considerations. Beehive size affects the internal temperature stability: overly large hives may be too cold, while small hives may overheat. In BG, beehives are generally 40-50 cm × 40 cm × 35 cm. In the DE, 40 cm × 40 cm × 35 cm. In MB, 35 cm × 35 cm × 30 cm beehives. *Glodok*-type hives are cylindrical with an entrance hole.

### Beehive site preferences

Generally, beekeeping was carried out in the forests, home gardens, and agricultural fields. Most beekeepers (BG: 40%; DE: 71%; MB: 67%) preferred forest areas, followed by agricultural land. These patterns were statistically comparable among BG, DE, and MB (Fisher's Exact Test,  $p=0.743$ ), and all pairwise comparisons were not significant ( $p\geq 0.467$ ). Informants reported that agricultural areas commonly implement agroforestry systems that support beekeeping through secondary crops such as corn (*Zea mays*), soybeans (*Glycine max*), and coffee (*Coffea* sp.). Besides land use covers, beekeepers also consider abiotic factors when selecting a beehive site (Figure 5).

**Table 1.** Informant characteristics

Beekeeping sites	Informants
Batu Garok	Leader of Asy-Syifa Babussalam KTH
Batu Garok	30 years of experience as a beekeeper
Deer Enclosure	Leader of the Deer Enclosure community
Deer Enclosure	22 years of experience as a beekeeper
Maribaya	Leader of Sari Alam KTH and a 25-year experienced as a beekeeper

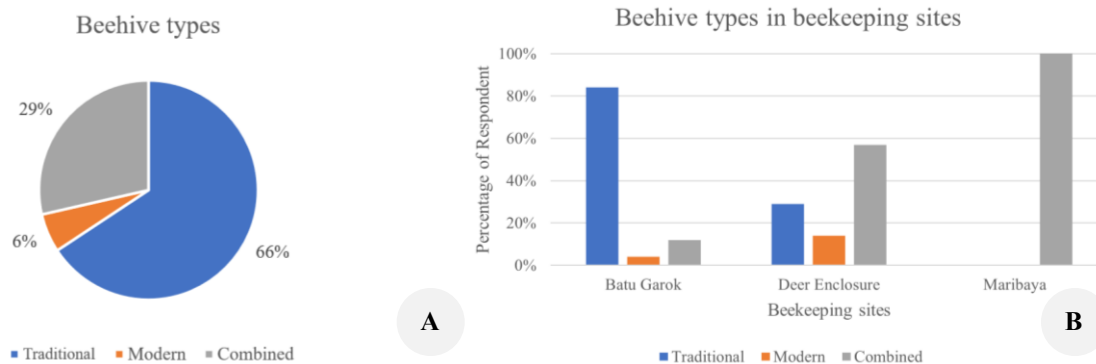
Note: KTH: Forest Farmers Group

**Table 2.** Respondent profiles

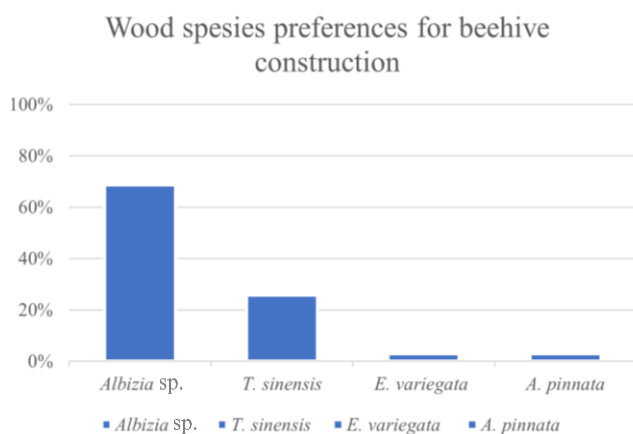
	No. of individual	%
Gender		
Male	29	82.90%
Female	6	17.10%
Age (y.o.)		
20-40	8	22.90%
40-60	25	71.40%
>60	2	5.70%
Last education		
Elementary school	16	45.70%
Junior high school	6	17.10%
Senior high school	9	25.70%
Associate's degree	1	2.90%
Bachelor's degree	3	8.60%
Livelihood		
Factory workers	11	31.40%
Beekeepers	6	17.10%
Entrepreneurs	7	20.00%
Farmers	4	11.40%
Part-time workers	3	8.60%
Housewife	3	8.60%
Civil servant	1	2.90%
Beekeeping experience (year)		
<10	24	68.60%
10-20	7	20%
21-30	3	8.60%
>30	1	2.90%



**Figure 2.** Traditional and modern beehive used for beekeeping in Ir. H. Djuanda Great Forest Park, West Java, Indonesia. The figure illustrates the designs used by beekeepers. A and B. Traditional hives made from wooden logs or simple wooden boxes, which allow bees to build comb structures freely; and C and D. Modern hives equipped with removable frames that separate honey storage from brood areas, enabling more hygienic harvesting. Source: Primary Data (2025)



**Figure 3.** Beehive type used by beekeepers in Ir. H. Djuanda Great Forest Park (n=35). A. The overall proportion of beehive types used by respondents, B. Beehive types across sites, illustrating differences in technology adoption across sites



**Figure 4.** Preference of wood species in the hive construction (n=35). The figure presents the proportion of beekeepers using different wood species, *Albizia* sp., *Toona sinensis*, *Erythrina variegata*, and *Arenga pinnata*, for beehive construction. These materials differ in weight, durability, temperature regulation, and affordability, influencing beekeepers' choices. Source: Primary Data (2025)

Most beekeepers agreed that floral resource availability is a key factor in beehive placement (Figure 5). They emphasized that an ideal beekeeping site should be surrounded by diverse, year-round flowering plants. Red calliandra (*Calliandra calothyrsus*) was identified as the primary food source for *A. cerana* due to its wide distribution and continuous nectar supply.

Most beekeepers said that sunlight exposure (80%) is also essential. The optimal orientation is facing east, toward sunrise. Beehives should not be placed under dense canopy cover to ensure ease of flight. According to informants, east-facing hives receive *balebat*, the soft morning light that appears before sunrise, around 5:00 AM, which stimulates earlier worker activity.

Most beekeepers (77%) considered water sources essential. They said beehives should be located near clean, flowing water, especially during prolonged dry periods when bees require more water to regulate the hive temperature. Beekeepers (83%) also emphasized topography due to its influence on bees' energy use. Valley

areas allow bees to conserve energy when returning with loads, giving them more time to forage and produce honey.

### Colony management practices

*A. cerana* colonies were obtained by capturing wild colonies in the forests. Beekeepers typically use trap hives placed in tree hollows, rock crevices, and beneath large tree roots along cliffs. Beekeepers said that *A. cerana* prefer cool environments with moderate sunlight and abundant, diverse food sources.

The beekeepers described seasonal variations in trap placement. During the dry season, traps were placed in lower areas, such as valleys or near water sources, to maintain a stable internal temperature. In the rainy season, traps were deployed in higher, drier areas, such as cliffs or the upper forest areas, or hung in trees to avoid rain splashes. Bees prefer elevated, dry areas as they provide better protection against flooding, terrestrial predators, and excess moisture.

The time required to capture a colony varies depending on weather and trap-site conditions, ranging from a week to several months or even a year. Once trapped, colonies are transferred to the site. The transfers were conducted during inactive hours to minimize disturbance and reduce the risk of stings. Most beekeepers (74%) preferred evening transfer (Figure 6), arriving around 05:30 PM and transferring between 06.00 and 06.30 PM after bees had returned to the hive.

A total of 43% of beekeepers reported transferring colonies at night, but 57% avoid this period due to limited lighting and safety concerns in forests. Only 23% transferred colonies early in the morning, arriving between 05:00 and 06:00 AM, before foraging begins. However, 77% said morning transfers are less effective because bees may start foraging early, increasing disturbance and the risk of absconding.

### Beehive maintenance practices

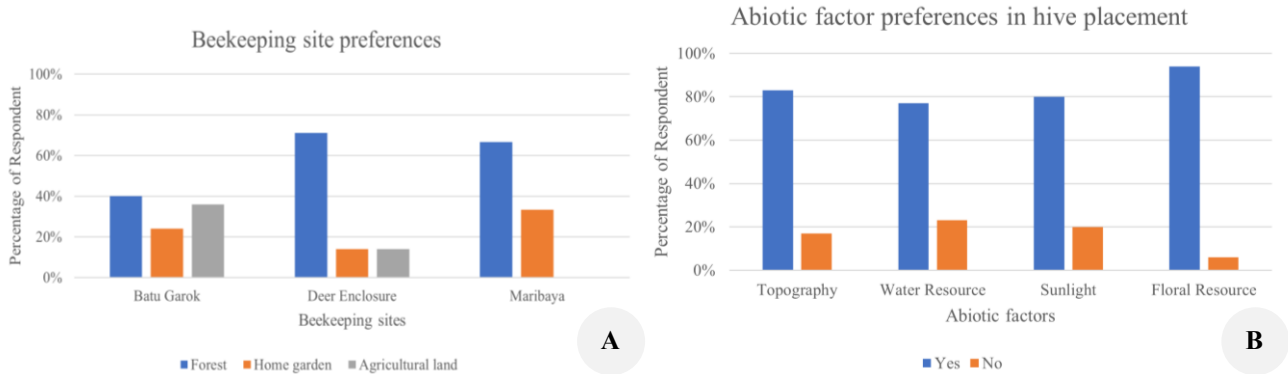
The most frequently used maintenance practice is harvesting readiness (80%) (Figure 7). Natural enemies control and colony monitoring are also key activities (71%). Beekeepers typically check for natural enemies weekly to ensure that colonies are not disturbed and hives

remain intact. Colony monitoring allows beekeepers to assess colony development, including drone numbers and potential queen bees. During the dry season, when natural food sources become scarce, beekeepers employ several strategies. In BG and DE, they provide supplemental feeding using diluted leftover honey or *A. pinnata* syrup. They also plant *Coffea* trees around sites to increase nectar availability. MB beekeepers refrain from harvesting honey during the dry season, allowing the stored honey to serve as the colony's primary food source. Instead, they harvest *A. dorsata* forest honey and enrich nectar availability by planting *C. calothyrsus* in home gardens.

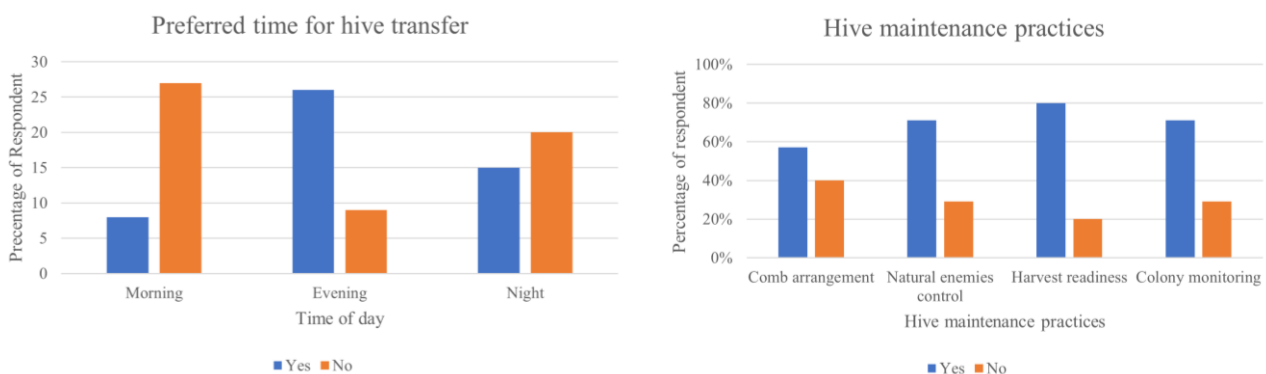
Beekeepers also implement strategies to prevent absconding, which often occurs when colonies split during the mating season (March-May) when floral resources are abundant. In BG, beekeepers store honey inside the hives and relocate them to shaded areas while minimizing hive disturbance. The DE beekeepers place empty hives around the site to capture new colonies that may split from the parent colony, preventing colony loss. In MB, the

beekeepers take a more direct approach by removing several potential queen bees to reduce the colony division. Comb arrangement (57%) was the least frequently performed activity. It is typically conducted only in *glodok* hives made from hollow tree trunks, which contain areas difficult to access. Rearranging the combs may disturb the bees, so this activity is rarely undertaken.

The beekeepers said that protecting hives from strong winds, pests, and competitors is essential, as safeguarding the hive ultimately protects the colony. A standard method is securing the hive to a support pole with ropes or wires to keep it stable during strong winds. The top of the hives is typically covered with plastic to protect them from rain. Beekeepers also apply oil to support poles to deter ant infestations and construct shelters, such as roofed racks, plastic tarpaulin, banana leaves, or palm fibers (known as *ijuk*), to reduce direct sunlight exposure. Besides, fences are often installed around the site to prevent disturbances from *M. fascicularis* and civets.



**Figure 5.** Beekeeping site preferences based on abiotic factors and land covers (n=35). A. The preferred land-cover types used for beekeeping across sites (Batu Garok, Deer Enclosure, and Maribaya), including forest areas, home gardens, and agricultural land. B. The proportion of beekeepers who consider key abiotic factors, topography, water sources, sunlight exposure, and floral resource availability, when determining beehive placement. Together, these figures illustrate how both landscape characteristics and abiotic factors influence site selection



**Figure 6.** Preferred time for hive transfer (n=35). The figure presents the proportion of beekeepers who relocate colonies in the evening, at night, or in the early morning. These preferences reflect efforts to minimize disturbance and reduce the risk of colony absconding during transfer

**Figure 7.** Hive maintenance practices (n=35). The figure presents the proportion of beekeepers conducting different maintenance activities, including harvest readiness checks, natural enemy control, colony monitoring, and comb arrangement. These practices show efforts to maintain colony health and ensure sustainable honey production

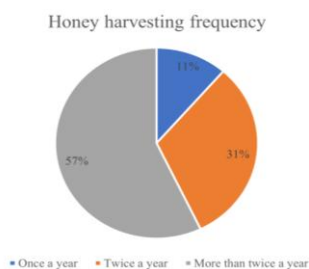
### Harvesting and marketing

Honey harvesting is conducted using two primary methods: traditional and modern. In the traditional method, honey is obtained by manually destroying the honeycomb. In contrast, in the modern method, a honey extractor is used to separate honey from the comb without damaging its structure. All beekeepers continue to employ the traditional method for honey harvesting.

The harvesting process begins by smoking the hive entrance to drive the bees away. Once the bees have vacated, harvest-ready combs are cut with a knife. In *glodok* or box hives, the combs containing honey are separated from those containing brood. However, in hives equipped with frames, it is sufficient to cut only the upper part of the comb to release the honey. The harvested honeycombs are then crushed using a wooden tool wrapped in plastic. The honey is subsequently extracted either by draining or manually squeezing the crushed comb. Draining is generally preferred when harvesting larger quantities of honey, typically over 10 kilograms.

In the draining technique, the honeycomb is filtered using gauze and hung to allow the honey to drip naturally into a container placed below. This process typically lasts overnight or up to 24 hours. In contrast, the manual extraction technique is faster: the honeycomb is wrapped in gauze and squeezed by hand until the honey is extracted. The collected honey, obtained by draining or squeezing, is then poured into bottles for marketing and subsequently stored in a cool, dry place.

Honey extracted through draining tends to be more transparent, whereas honey extracted by squeezing is cloudier due to the inclusion of solid particles such as pollen, larvae, and wax. Moreover, honey extracted through squeezing crystallizes more rapidly and is locally referred to as crystallized honey. During the harvesting process, only two-thirds of the total honey is produced, while the remaining honey is kept as a food supply for the colony. Honey characteristics are generally consistent and are commonly referred to as calliandra honey. It has a distinctive product of the area. The widespread presence of *C. calothyrsus* in the forest provides an abundant, continuous nectar source, resulting in honey that is similar in color, taste, and aroma. Beekeepers describe it as yellow, fragrant, and sweet. They also note that crystallization is a natural process typical of honey with high sugar content.



**Figure 8.** Honey harvesting frequency (n=35). The figure presents how often beekeepers harvest honey each year, once, twice, or more than twice, highlighting variations in colony productivity, floral availability, and management conditions across beekeeping sites

Because *C. calothyrsus* nectar contains a high concentration of sugars, the honey tends to crystallize within one or two months after harvesting, depending on extraction and storage conditions.

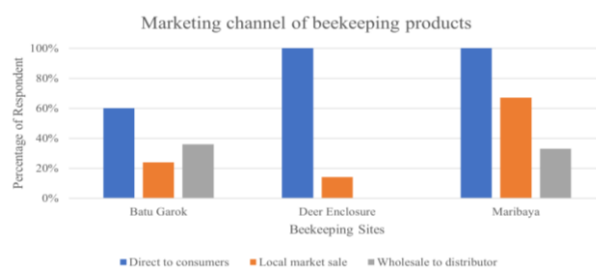
The frequency of annual honey harvesting varied among sites. Figure 8 presents the number of yearly harvests conducted by beekeepers in DGFP. Most beekeepers (57%) harvested honey more than twice per year, while 31% conducted two harvests annually, and only 11% harvested once a year. The number of *A. cerana* hives managed by beekeepers in the three sites also varied. In BG, the number of hives ranged from 1 to 50, while in DE, it ranged from 2 to 50. In contrast, all beekeepers in MB maintained 50 beehives each. Honey yield per site also showed considerable variation. In BG, total honey production ranged from 3 to 16 kilograms per harvest, while in DE, it ranged from 2 to 50 kilograms. In MB, the yield ranged from two to 100 kg. These differences were statistically significant (Fisher's Exact Test,  $p=0.047$ ). Post-hoc analyses showed that the contrast between BG and DE was significant ( $p=0.035$ ), whereas the contrasts between BG and MB ( $p=0.351$ ) and between DE and MB ( $p=0.625$ ) were not.

The honey bee products produced and marketed by beekeepers varied among sites (Table 3). The BG group sells a variety of products, including honey, pollen, propolis, royal jelly, bee colonies, and beeswax. Most beekeepers market their products directly to consumers, either through on-site sales or private orders. Besides, some beekeepers distribute their products through local markets and wholesale distributors (Figure 9).

**Table 3.** Beekeeping products

Products	Sites		
	BG	DE	MB
Honey	✓	✓	✓
Pollen	✓		
Propolis	✓		✓
Royal jelly	✓		✓
Bee colonies	✓	✓	✓
Beeswax	✓		

Note: BG: Batu Garok; DE: Deer Enclosure; MB: Maribaya, Source: Primary Data (2025)



**Figure 9.** Beekeeping product sales (n=35). The figure presents the types of honey bee products sold across the three beekeeping sites, including raw honey, pollen, propolis, royal jelly, beeswax, and bee colonies. Differences in product diversity show variations in resource availability, technical skills, and access to specialized equipment among beekeepers

## Discussion

Beekeeping practices documented in the DGFP show how closely local communities observe and learn from their surroundings, such as the characteristics, behavior, and life cycle of *A. cerana*. Their ability to identify queens, workers, and drones by morphology demonstrates a practical understanding of taxonomy, which helps them assess colony health and identify queen replacements. The queen produces eggs that resemble small, elongated rice grains (Pradeep et al. 2023). They have mouths but no legs or wings (Pradeep et al. 2023). They also understand the bee life cycle to support their key management decisions. Understanding the life cycle of bees enables them to assess the colony's health and productivity. Fewer larvae are an early indication of stress, disease, or lack of food. This accuracy reflects a form of local expertise that is also evident in how they monitor colony development in the later stages of management.

Their choice to cultivate *A. cerana* is based on experience, which they describe as a docile, hygienic bee highly adaptable to the local environment. Katuwal et al. (2023) state that *A. cerana* has effective and hygienic self-care behavior. It is easy to cultivate, requires little care and is suitable for use as a source of side income or to fill spare time. These observations explain why *A. cerana* remains the species of choice, even though other honey bees are also known in the area.

The strong reliance on traditional hives, such as BG, suggests that beekeeping knowledge remains embedded in long-standing local practices (Figure 3). Traditional hives are easy to build from available materials and allow *A. cerana* to build hives freely, which is often associated with higher honey yields. Selecting traditional hives can also minimize production costs. DE and MB, on the other hand, use both traditional and modern hives, indicating that beekeepers there have greater access to training opportunities and equipment resources. The use of a combination of hive types suggests a willingness to experiment with techniques that improve honey quality. These patterns show that the adoption of technology in beekeeping is influenced by environmental, opportunity, and ecological factors.

The nature of the wood and the dimensions selected affect the hive's microclimate, as temperature and humidity play essential roles in maintaining colony homeostasis within the hive (Abou-Shaara et al. 2017; Lepkova et al. 2022; Herdananta et al. 2025). The preference for lightweight and affordable *Albizia* wood reflects practical considerations, as previous studies have reported that the lebbeck tree (*Albizia lebbeck*) is widely used by beekeeping farmers due to its low cost and durability (Aishwarya et al. 2022). Similarly, *A. cerana* has been reported to naturally select light-colored wood, such as *Albizia*, for nesting (Biswas and Gupta 2021). The selective use of *T. sinensis* may also be related to its aromatic characteristics, which are perceived as attractive to bees. This species is known to produce a complex and strong aroma composed of volatile compounds commonly associated with plant-pollinator interactions; however, direct behavioral experiments testing bee responses to *T. sinensis* scent are still lacking, so its

attractiveness to bees remains plausible but unproven (Wang et al. 2023). In addition, *E. variegata* is used for its perceived heat resistance and temperature-regulation properties (Figure 4), as materials that insulate heat and humidity can improve hive conditions for honey bee colonies (Erdoğan 2019). Comparable practices have also been reported elsewhere, where durable and aromatic woods such as surian (*Toona sureni*) are widely used in log hive construction due to their durability, ease of processing, and natural fragrance, which may help deter pests and pathogens (Cheng et al. 2020).

Interactions with natural enemies pose challenges in maintaining bees in forest landscapes. Geckos, ants, wax moths, wasps, spiders, civets, monkeys, and other honey bees routinely threaten colonies. Ants are one of the most common bee pests that attack hives, especially when colonies are weak, to steal pollen, honey, eggs, and even larvae or pupae (Satyapriya et al. 2024). Wax moths lay eggs in poorly maintained hives, and their larvae tunnel through the hive cells while eating wax, pollen, and bee larvae (Dwarka et al. 2025). Wasps are larger than *A. cerana*, have venomous stingers, and can kill many worker bees (Satyapriya et al. 2024). Because this threat is common, many beekeepers monitor their hives regularly (71%; Figure 7). The reliance on simple physical barriers (such as fences and oil on poles) suggests that hive maintenance can be carried out using locally available, recycled materials. Other honeybees and monkeys compete for food at the same time as *A. cerana* in the morning, where monkeys eat *C. calothyrsus* flowers. *A. cerana* forages between 06:00-10:00 AM and 01:00-04:00 PM (Shullia et al. 2024). Meanwhile, *A. dorsata* can forage both during the day and at night (Young et al. 2021). These adaptive responses demonstrate how ecological pressures in forest landscapes directly shape daily management practices.

The preference for forested areas is closely tied to the floral diversity in the DGFP, particularly the red calliandra (*C. calothyrsus*), which blooms year-round (Wulandari et al. 2025). This continuous food supply helps maintain strong, productive colonies even during seasonal scarcity. The placement of the beehive also aligns with abiotic factors that influence foraging efficiency (Figure 5), such as east-facing nests receiving morning sunlight, which stimulates morning foraging activity. At the same time, valley areas reduce the energy required for flight. Honey bees prefer flat areas below the foraging site because flying uphill is difficult due to gravity (Mahbub et al. 2019). Access to nearby water further strengthens colony performance, as water is essential for cooling the hive when internal temperature rises; bees actively collect and evaporate water to maintain temperature below about 34.5°C. Sunlight intensity also affects bee foraging behavior, as bees remain inactive when ambient temperatures are too low (Nuraini et al. 2020). Altogether, these biotic and abiotic factors create an environment that supports colony growth and stable honey yields.

Colony management practices follow seasonal patterns. Moving colonies at night reduces stress and the risk of absconding (Figure 6) because the workers have returned to

the hive. Strategies for preventing absconding vary by site. They all target reproductive signals or the underlying environment. These include storing extra honey in the hive, placing the beehive in a shaded area, placing empty hives to capture swarms, and removing excess queen bees. Each approach targets different factors, from availability to swarm behavior, and shows how maintenance decisions respond directly to colony signals. Dry-season strategies varied across sites, but all aimed to protect the colony's food supply. BG and DE provided colonies with diluted honey or *A. pinnata* syrup supplements, while MB refrained from harvesting altogether, enabling colonies to rely on stored honey. These differences highlight how environmental conditions and livelihood options shape beekeeping practices across sites.

Harvest readiness, as the most common maintenance practice (Figure 7), indicates that beekeepers prioritize honey quality and colony stability. This priority aligns with the heavy reliance on floral resources (Figure 5), where honey yield depends on seasonal blooming cycles. Careful timing of harvests helps ensure that colonies retain enough food reserves to remain healthy, especially during periods when nectar becomes scarce. The finding that beekeepers regularly monitor for natural enemies weekly shows that they recognize how disturbances can reduce honey production and provoke absconding.

Traditional honey harvesting, which involves cutting and crushing the hive, is consistent with the prevalence of conventional hives. In the dripping or draining method, the crushed honeycomb is placed in a cloth filter and left to drain naturally. As the honey slowly passes through the fabric, small particles, such as wax residues and debris, are removed, producing a clearer product (Evahelda et al. 2024). Conversely, Awwaly et al. (2022) said that honey extracted through squeezing is typically cloudier due to the mixture of pollen. The presence of small amounts of pollen and other particulates can act as crystallization nuclei, promoting crystal aggregation and thereby accelerating the crystallization process (Ji et al. 2023). A consistent practice across all sites is to leave a third of the honey in the hive. This food reserve supports the colony's survival during periods of poor flowering and aligns with broader dry-season management patterns. These practices demonstrate an environmentally conscious approach that is embedded in daily harvesting routines.

However, honey production varies significantly across sites (Figure 8), reflecting uneven access to forage, differences in hive types, and variations in technical experience. Higher honey production and larger colony numbers in MB suggest greater access to resources, equipment, or institutional networks. Beekeepers are almost entirely focused on selling raw honey to the customers (Table 3 and Figure 9), as it is the most reliable product to produce. Diversification into products such as pollen or propolis is relatively limited, as this requires specialised tools and training. For instance, pollen traps could cause colonies to abandon the hive by preventing pollen, a vital resource for larval development, from returning to the colony (Husodo et al. 2024).

In conclusion, this study shows that *A. cerana* beekeeping in DGFP is grounded in a deep local ecological knowledge system that guides practical decisions on beehive construction, site selection, seasonal colony management, harvesting, and marketing. These findings reveal that local knowledge is not merely a cultural practice but also a critical component of the forest park's socio-ecological system, enabling beekeepers to adapt to flowering seasons, microclimate changes, and resource constraints. Recognizing this contribution is essential to designing interventions that support the community's ecological resilience and livelihoods. Future research should prioritize long-term monitoring of colony health and productivity, as well as economic assessments of beehive types and product diversification. At the policy level, integrating local knowledge into DGFP management plans, through appropriate beekeeping zoning, targeted technical training, and support for value-added product development, can strengthen sustainable beekeeping and reinforce its role in the broader forest landscape.

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